ENHANCED SMART DSL SYSTEMS FOR LDSL

Related Applications

[0001] The present invention claims priority to U.S. Provisional Application Nos. 60/488,804 filed July 22, 2003 and 60/426,796 filed November 18, 2002, the contents of which are incorporated herein by reference in their entirety.

[0002] This application is related to copending U.S. Patent Applications titled "SYSTEM AND METHOD FOR SELECTABLE MASK FOR LDSL," (Attorney Docket No. 56162.000456) which claims priority to U.S. Provisional Patent Application No. 60/441,351, "ENHANCED SMART DSL FOR LDSL," (Attorney Docket No. 56162.000484) which claims priority to U.S. Provisional Application No. 60/488,804 filed July 22, 2003 and "POWER SPECTRAL DENSITY MASKS FOR IMPROVED SPECTRAL COMPATIBILITY" (Attorney Docket No. 56162.000485) which claims priority to U.S. Provisional Application No. 60/491,268 filed July 31, 2003, all filed concurrently herewith.

BACKGROUND OF THE INVENTION

Field of the Invention

[0003] This invention relates to digital subscriber lines (DSL) and to smart systems for implementing Long reach Digital Subscriber Lines (LDSL).

Description of Related Art

[0004] High level procedures for meeting stated objectives for Long reach Digital Subscriber Line (LDSL) transmissions are disclosed. Some objectives for LDSL have been defined in publications available from standards organizations such as the International Telecommunications Union (ITU). For example, ITU publications OC-041R1, OC-045, OC-073R1, OJ-030, OJ-036, OJ-060, OJ-061, OJ-062, OJ-200R1, OJ-200R2, OJ-201, OJ-60R1, OJ-60R2 and OJ-210 set forth some LDSL objectives. Other objectives, standards and criteria for LDSL are also possible and may be accommodated by the disclosed inventions.

[0005] One LDSL target objective is to achieve a minimum payload transmission of 192 kb/s downstream and 96 kb/s upstream on loops having an equivalent working length of 18 kft 26 gauge cable in a variety of loop and noise conditions. One difficulty in achieving these target transmission rates is the occurrence of crosstalk noise.

[0006] The crosstalk noise environments that may occur for the above bit rate target objective are varied. For example, noise environments may include Near-end cross talk (NEXT), Far-end cross talk (FEXT), disturbance from Integrated Services Digital Networks (ISDN), High Speed Digital Subscriber Lines (HDSL), SHDSL, T1, and Self-disturbers at both the Central Office (CO) and Customer Premise Equipment (CPE) ends. NEXT from HDSL and SHDSL tend to limit the performance in the upstream channel, while NEXT from repeatered T1 AMI systems tend to severely limit the downstream channel performance. An additional source of noise is loops containing bridged taps that degrade performance on an Asymmetric Digital Subscriber Line (ADSL) downstream channel more so than the upstream channel.

[0007] Another drawback of existing systems is that it appears very difficult to determine a single pair of Upstream and Downstream masks that will maximize the performance against any noise-loop field scenario, while ensuring spectral compatibility and, at the same time, keeping a desirable balance between Upstream and Downstream rates.

[0008] One approach for LDSL relies on different Upstream and Downstream masks exhibiting complementary features. Realistically, all these chosen masks are available on any LDSL Platform. At the modem start up, based on a certain protocol, the best Upstream-Downstream pair of masks is picked up. Whether the best pair is manually chosen at the discretion of the operator, or automatically selected, this concept is identified as "smart DSL for LDSL".

[0009] There are many reasons to implement smart DSL. For example, non-smart DSL systems may implement a single mask for upstream and downstream transmissions.

A drawback with this approach is that the use of a single mask may prevent LDSL service in areas of the United States dominated by T1 noise.

[0010] In addition, the use of a single mask is a drawback because the existence of other spectrally compatible masks cannot be ruled out. LDSL service providers will want to have access to an array of mask/tools provided they are spectrally compatible. Service providers may decide to use only one mask according to the physical layer conditions, or any combination of masks for the same or other reasons.

[0011] Another advantage of Smart DSL is that it is a good way to handle providing LDSL services in different countries. For example, so far, LDSL work has focused on SBC requirements. As a result, it is risky of, for example, a US-based LDSL provider to rely on the ability to apply any masks that pass SBC tests to Europe, China or Korea. LDSL is a difficult project and essential for all the countries. Therefore, any scheme for LDSL standardization that takes into account merely SBC physical layer and cross talk requirements may jeopardize the ADSL reach extension in non-standard LDSL countries. Other drawbacks of current systems also exist.

SUMMARY OF THE INVENTION

[0012] A "Smart DSL System" for addressing the performance objectives of LDSL and examples of smart systems for LDSL are disclosed.

[0013] In accordance with embodiments of the invention, there is disclosed a method for implementing smart DSL for LDSL systems. Embodiments of the method may comprise presenting a number of spectral masks that are available on the LDSL system, and selecting from the number of spectral masks an upstream mask and a downstream mask wherein the upstream mask and the downstream mask exhibit complimentary features.

[0014] In some embodiments the method may further comprise selecting the upstream mask and the downstream mask during a modem start up period. Still further,

embodiments of the invention may comprise selecting the upstream mask and the downstream mask manually or automatically.

[0015] In accordance with some embodiments of the invention, there is disclosed a method for implementing smart DSL for LDSL systems. In some embodiments, the method may comprise defining a candidate system to be implemented by an LDSL system, optimizing criteria associated with the candidate system, and selecting a candidate system to implement in an LDSL system.

[0016] In accordance with some embodiments of the invention, the method may further comprise determining features of upstream and downstream transmission. The method may further comprise determining one or more of: cut-off frequencies, side lobe shapes, overlap, partial overlap or FDD characteristics.

[0017] In some embodiments, the method may further comprise optimizing criteria associated with the candidate system to fulfill upstream and downstream performance targets and selecting a spectral mask for use with upstream or downstream transmission.

[0018] In accordance with some embodiments of the invention there is provided a method for implementing smart DSL for LDSL systems. In some embodiments the method may comprise selecting a spectral mask based upon performance criteria;, and activating the selected spectral mask based at least one of customer premise or central office capabilities.

[0019] In accordance with further aspects of the invention, the method may further comprise selecting the spectral mask is performed manually or automatically. Other advantages and features of the invention are discussed below.

<u>BRIEF DESCRIPTION OF THE DRAWINGS</u>

[0020] Figure 1 is a graph illustrating peak values for U1 and D1 PSD masks according to embodiments of the invention.

[0021] Figure 2 is a graph illustrating peak values for U2 and D2 PSD masks according to embodiments of the invention.

[0022] Figure 3 is a graph illustrating average values for U3 and D3 PSD templates according to embodiments of the invention.

[0023] Figure 4 is a bar chart illustrating upstream rate, noise case #1, for ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0024] Figure 5 is a bar chart illustrating upstream rate, noise case #2, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0025] Figure 6 is a bar chart illustrating upstream rate, noise case #3, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0026] Figure 7 is a bar chart illustrating upstream rate, noise case #4, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0027] Figure 8 is a bar chart illustrating upstream rate, noise case #5, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0028] Figure 9 is a bar chart illustrating upstream rate, noise case #6, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0029] Figure 10 is a bar chart illustrating upstream rate, noise case #7, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0030] Figure 11 is a bar chart illustrating upstream rate, noise case #T1, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0031] Figure 12 is a bar chart illustrating downstream rate, noise case #1, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0032] Figure 13 is a bar chart illustrating downstream rate, noise case #2, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0033] Figure 14 is a bar chart illustrating downstream rate, noise case #3, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0034] Figure 15 is a bar chart illustrating downstream rate, noise case #4, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0035] Figure 16 is a bar chart illustrating downstream rate, noise case #5, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0036] Figure 17 is a bar chart illustrating downstream rate, noise case #6, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0037] Figure 18 is a bar chart illustrating downstream rate, noise case #7, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0038] Figure 19 is a bar chart illustrating downstream rate, noise case #T1, ADSL2, M OJ-074, NON EC Smart LDSL systems in accordance with embodiments of the invention.

[0039] Figure 20 is a bar chart illustrating upstream rate, noise case #1, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0040] Figure 21 is a bar chart illustrating upstream rate, noise case #2, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0041] Figure 22 is a bar chart illustrating upstream rate, noise case #3, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0042] Figure 23 is a bar chart illustrating upstream rate, noise case #4, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0043] Figure 24 is a bar chart illustrating upstream rate, noise case #5, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0044] Figure 25 is a bar chart illustrating upstream rate, noise case #6, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0045] Figure 26 is a bar chart illustrating upstream rate, noise case #7, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0046] Figure 27 is a bar chart illustrating upstream rate, noise case #T1, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0047] Figure 28 is a bar chart illustrating downstream rate, noise case #1, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0048] Figure 29 is a bar chart illustrating downstream rate, noise case #2, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0049] Figure 30 is a bar chart illustrating downstream rate, noise case #3, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0050] Figure 31 is a bar chart illustrating downstream rate, noise case #4, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0051] Figure 32 is a bar chart illustrating downstream rate, noise case #5, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0052] Figure 33 is a bar chart illustrating downstream rate, noise case #6, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0053] Figure 34 is a bar chart illustrating downstream rate, noise case #7, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0054] Figure 35 is a bar chart illustrating downstream rate, noise case #T1, ADSL2, M OJ-074, EC Smart LDSL systems in accordance with embodiments of the invention.

[0055] Figure 36 illustrates a flow diagram for selecting a pair of masks in a smart DSL system in accordance with embodiments of the invention.

[0056] Figure 37 is a state diagram illustrating options for selecting a pair of masks in a smart DSL systems in accordance with embodiments of the invention.

[0057] Figure 38 illustrates an option for implementing smart DSL systems in accordance with embodiments of the invention.

[0058] Figure 39 illustrates an option for implementing smart DSL systems in accordance with embodiments of the invention.

[0059] Figure 40 illustrates an option for implementing smart DSL systems in accordance with embodiments of the invention.

[0060]

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0061] Smart DSL Concept for LDSL.

[0062] This section defines a Smart DSL concept for LDSL. In some embodiments, operating with smart DSL systems for LDSL may include the below listed steps. The first and second steps may be completed, in some embodiments, during a standardization process and other steps may be performed during a modem's handshake/initialization phase in order to optimize the performance for any type of loops and noises.

[0063] Step 1. Smart DSL Systems members for LDSL (S).

[0064] In some embodiments it is preferable to complete step 1 during standardization processes. Alternatively, step 1 may be performed off line, for example, if no standardization is at stake.

[0065] In some embodiments, the first step consists of defining candidate systems that aim to be picked up based on optimization criteria defined below. Typically, these candidate systems may exhibit sufficient versatility features for both Upstream and Downstream spectra, such as cut off frequencies, side lobes shapes, overlap, partial overlap, FDD characteristics, etc.

[0066] In some embodiments it may be desirable for candidate systems to also meet additional constraints. For example, an additional constraint may be that no new channel coding scheme should be considered in the candidate systems. In this manner, smart DSL systems in accordance with the invention exhibit several degrees of freedom that are summarized in what follows by parameter set S.

[0067] Step 2. Optimization criteria (C).

[0068] In some embodiments, it is preferable that the second step be completed during the standardization process. Alternatively, the second step may be completed off line if no standardization is at stake.

[0069] The second step comprises defining optimization criteria. Optimization criteria drive smart DSL systems members definition and, of course, the performance outcomes. For some embodiments, optimization criteria (C) may be summarized as covering Upstream and Downstream performance targets. In addition, optimization criteria may cover the margin within which performance targets should be met, such as, whether the deployment is Upstream or Downstream limited. The last point is important since often, in order to keep the optimization process simple priority should be given to Upstream or Downstream channels.

[0070] In some embodiments, optimization criteria may also comprise spectral compatibility requirements. This criteria may also include assumptions about neighboring services. Other optimization criteria are also possible.

[0071] Step 3. Choice of an optimal system amongst the smart DSL systems candidates (S*).

[0072] In some embodiments it may be preferable to complete step 3 during handshake/initialization. Completing step 3 during handshake/initialization may enable better handling of any type of loops and noise/cross talk conditions. Alternatively, this step could be completed off line, for example, if the operator has accurate prior knowledge of loops and noise conditions.

[0073] In some embodiments, completion of step 3 may be as simple as picking up one of two masks already defined. In other embodiments, completion of step 3 may comprise tuning a continuous parameter such as a cut off frequency. Other methods of completing step 3 are also possible.

[0074] In some embodiments, the outcome of step 3 may comprise an optimal system (S*) that will be run by the modem in the conditions that lead to its optimality.

[0075] Two Examples of Smart DSL system for LDSL, based on SBC requirements.

[0076] Example 1: Definition of the Masks to be used in the two smart systems.

[0077] Three Upstream masks U1, U2, U3 and three Downstream masks D1, D2, D3 are used in what follows to define embodiments of smart systems. U1 (dashed line) and D1 (solid line) masks are plotted in Figure 1. Note that in this section the masks for peak values are defined. As defined by some standards, the PSD templates, or average PSD values, are 3.5 dB lower than the mask values. Tables 1 and 2 show some values for U1 and D1 (respectively) according to some embodiments of the invention.

Frequency Band f (kHz)	**Equation for the PSD mask (dBm/Hz)**
$0 < f \leq 4$	–97.5, with max power in the in 0-4 kHz band of +15 dBrn
$4 < f \leq 25.875$	$-92.5 + 23.43 \times \log_2(f/4)$;
$25.875 < f \leq 60.375$	–29.0
$60.375 < f \leq 90.5$	$-34.5 - 95 \times \log_2(f/60.375)$
$90.5 < f \leq 1221$	–90
$1221 < f \leq 1630$	–99.5 peak, with max power in the $[f, f + 1$ MHz$]$ window of $(-90 - 48 \times \log_2(f/1221) + 60)$ dBm
$1630 < f \leq 11\,040$	–99.5 peak, with max power in the $[f, f + 1$ MHz$]$ window of –50 dBm

Table 1. U1 PSD Mask Definition, peak values

Frequency Band f (kHz)	**Equation for the PSD mask (dBm/Hz)**
$0 < f \leq 4$	–97.5, with max power in the in 0-4 kHz band of +15 dBrn
$4 < f \leq 25.875$	$-92.5 + 20.79 \times \log_2(f/4)$
$25.875 < f \leq 81$	–36.5
$81 < f \leq 92.1$	$-36.5 - 70 \times \log_2(f/81)$
$92.1 < f \leq 121.4$	–49.5
$121.4 < f \leq 138$	$-49.5 + 70 \times \log_2(f/121.4)$
$138 < f \leq 353.625$	$-36.5+0.0139\times(f-138)$
$353.625 < f \leq 569.25$	–33.5
$569.25 < f \leq 1622.5$	$-33.5 - 36 \times \log_2(f/569.25)$
$1622.5 < f \leq 3093$	–90
$3093 < f \leq 4545$	–90 peak, with maximum power in the $[f, f+1$ MHz$]$ window of $(-36.5-36 \times \log_2(f/1104)+60)$dBm
$4545 < f \leq 11040$	–90 peak, with maximum power in the [f, f+1 MHz] window of –50 dBm

Table 2. D1 PSD Mask Definition, peak values

[0078] According to some embodiments of the invention U2 (dashed line) and D2 (solid line) spectrum masks may be plotted as shown in Figure 2. Note that, as above, the masks for peak values are defined. The PSD templates, or average PSD values, are 3.5 dB lower than the mask values. Tables 3 and 4 show some values for U2 and D2 (respectively) in accordance with some embodiments of the invention.

Frequency Band f (kHz)	Equation for the PSD mask (dBm/Hz)
$0 < f \leq 4$	–97.5, with max power in the in 0-4 kHz band of +15 dBrn
$4 < f \leq 25.875$	$-92.5 - 22.5\times \log_2(f/4)$;
$25.875 < f \leq 86.25$	–30.9
$86.25 < f \leq 138.6$	$-34.5 - 95 \times \log_2 (f/86.25)$
$138.6 < f \leq 1221$	–99.5
$1221 < f \leq 1630$	–99.5 peak, with max power in the $[f, f + 1$ MHz$]$ window of $(-90 - 48 \times \log_2(f/1221) + 60)$ dBm
$1630 < f \leq 11\,040$	–99.5 peak, with max power in the $[f, f + 1$ MHz$]$ window of –50 dBm

Table 3. U2 Mask Definition, peak values

Starting Frequency (kHz)	Starting PSD mask value (dBm/Hz)
0.000000	-98.000000
3.990000	-98.000000
4.000000	-92.500000
80.000000	-72.500000
120.740000	-47.500000
120.750000	-37.800000
138.000000	-36.800000
276.000000	-33.500000
677.062500	-33.500000
956.000000	-62.000000
1800.000000	-62.000000
2290.000000	-90.000000
3093.000000	-90.000000
4545.000000	-110.000000
12000.000000	-110.000000

Table 4. D2 Mask Definition, peak values

[0079] Similarly, tables 5 and 6 give the breakpoints of U3 and D3 PSD Templates (*average values*) in accordance with some embodiments of the invention. Figure 3 shows U3 (dashed line) and D3 (solid line) according to some embodiments of the invention.

Frequency [KHz]	Nominal Upstream PSD [dBm/Hz]
0	-101.5
4	-101.5
4	-96
25.875	-36.30
103.5	-36.30
164.1	-99.5
1221	-99.5
1630	-113.5
12000	-113.5

Table 5. U3 Spectrum PSD Template, average values

Frequency [kHz]	Nominal Downstream PSD [dBm/Hz]
0	-101.5
4	-101.5
4	-96
80	-76
138	-47.5
138	-40
276	-37
552	-37
956	-65.5
1800	-65.5
2290	-93.5
3093	-93.5
4545	-113.5
12000	-113.5

Table 6. D3 Spectrum PSD Template, average values

[0080] Smart system scenario detection.

[0081] In this scenario, it is assumed that the Smart LDSL system has the capability either to analyze *a priori* the cross talk/physical layer conditions, or to pick up a mask after testing all of them based on performance and spectral compatibility

criteria. Under this feature, all the modems located in the same area will detect the same type of cross talk/impairments. Therefore, the worst case catastrophic scenario based on the use of all the possible masks at any location happens to be a completely unrealistic view for a genuine smart system. This feature was incorporated with success in the already deployed smart enhanced Annex C for Japan.

[0082] Example 1: NON EC Smart LDSL

[0083] Definition

[0084] In this exemplary embodiment, a first smart system makes use of U1, U2, U3 and D1, D3 masks. According to the features of all these masks, no Echo canceller is required by this embodiment of a smart system that will be identified as NON EC Smart LDSL.

[0085] Simulation Results

[0086] Tables 7 and 8 gives the ADSL2 upstream and downstream performance for calibration purposes.

		upstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne:	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
ADSL2	xDSL 10	1107	1107	596	294	305	570	646	1133
	xDSL 11	884	884	319	120	130	291	361	894
	xDSL 12	846	846	275	**90**	102	248	314	854
	xDSL 13	692	692	142	**48**	**54**	99	163	697
	xDSL 160	969	969	406	141	157	380	452	986
	xDSL 165	925	925	360	116	130	330	404	944
	xDSL 170	881	881	313	**94**	106	287	354	897
	xDSL 175	837	837	269	**78**	**89**	243	306	851
	xDSL 180	798	798	225	**63**	**74**	202	266	805
	xDSL 185	755	755	185	**51**	**60**	162	224	764

Table 7. ADSL2 Upstream Channel performance

		downstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne:	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
	xDSL 10	298	298	305	328	326	307	162	170
	xDSL 11	0	0	0	0	0	0	0	0
	xDSL 12	0	0	0	0	0	0	0	0
	xDSL 13	0	0	0	0	0	0	0	0
ADSL2	xDSL 160	300	300	303	323	321	303	88	91
	xDSL 165	201	201	203	224	224	207	43	49
	xDSL 170	125	125	113	141	140	123	8	13
	xDSL 175	59	66	57	74	74	63	0	0
	xDSL 180	0	8	12	17	17	12	0	0
	xDSL 185	0	0	0	0	0	0	0	0

Table 8. ADSL2 Downstream Channel performance

[0087] Tables 9 and 10 display the results of the Modified OJ-074. These results may be taken as references for LDSL.

		upstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne:	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
	xDSL 10	839	841	488	300	315	458	510	844
	xDSL 11	667	667	312	144	159	283	332	669
	xDSL 12	622	623	270	111	124	242	289	624
	xDSL 13	496	496	157	59	69	136	176	497
M OJ-074	xDSL 160	709	710	353	174	191	324	374	711
	xDSL 165	675	675	319	145	161	291	340	677
	xDSL 170	641	641	287	120	134	259	307	642
	xDSL 175	606	606	255	101	110	227	275	608
	xDSL 180	572	572	224	80	92	198	243	573
	xDSL 185	537	537	195	66	76	169	212	539

Table 9. M OJ-074 Upstream Channel Performance Results

		downstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne:	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
	xDSL 10	2396	1659	1784	2023	1991	1616	224	436
	xDSL 11	997	407	431	861	892	358	0	79
	xDSL 12	1202	643	622	974	969	546	0	48
	xDSL 13	855	398	449	696	776	350	0	52
M OJ-074	xDSL 160	2048	1333	1413	1752	1725	1268	150	331
	xDSL 165	1788	1086	1179	1527	1518	1027	92	261
	xDSL 170	1553	875	933	1326	1332	809	53	205
	xDSL 175	1343	754	755	1145	1163	648	25	152
	xDSL 180	1147	633	694	985	1011	579	4	111
	xDSL 185	978	529	608	840	872	500	0	76

Table 10. M OJ-074 Upstream Channel Performance Results

[0088] Tables 11 and 12 give the results of NON EC Smart LDSL system.

		upstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
NON EC SMART	xDSL 10	839	841	488	310	324	458	510	851
	xDSL 11	667	667	312	179	196	283	332	673
	xDSL 12	622	623	270	146	157	242	289	628
	xDSL 13	496	496	176	102	110	142	176	500
	xDSL 160	709	710	353	206	219	324	374	716
	xDSL 165	675	675	319	182	195	291	340	681
	xDSL 170	641	641	287	152	168	259	307	646
	xDSL 175	606	606	255	136	145	227	275	611
	xDSL 180	572	572	226	122	130	198	243	577
	xDSL 185	537	537	200	108	116	169	212	542

Table 11. NON EC Smart LDSL Upstream Channel Performance Results

		downstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
NON EC SMART	xDSL 10	2615	1711	1946	2148	2169	1679	224	572
	xDSL 11	1060	407	445	902	958	358	**0**	**135**
	xDSL 12	1265	643	634	998	1025	546	**0**	**105**
	xDSL 13	885	398	449	705	816	350	**0**	**79**
	xDSL 160	2156	1333	1466	1797	1816	1268	**150**	429
	xDSL 165	1885	1086	1222	1572	1604	1027	**92**	349
	xDSL 170	1639	875	967	1370	1413	809	**53**	278
	xDSL 175	1418	754	782	1187	1237	648	**25**	220
	xDSL 180	1213	633	720	1025	1079	579	**4**	**169**
	xDSL 185	1034	529	629	877	932	500	**0**	**126**

Table 12. NON EC Smart LDSL Downstream Channel Performance Results

[0089] Tables 13 and 14 give the selected Upstream and Downstream masks by the smart system. These tables confirm that, for this embodiment, a single mask can't handle all the noise scenarios and all the loops.

		Upstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
selection index	xDSL 10	3	3	3	2	2	3	3	3
	xDSL 11	3	3	3	2	2	3	3	3
	xDSL 12	3	3	3	1	2	3	3	3
	xDSL 13	3	3	2	1	1	2	2	3
	xDSL 160	3	3	3	2	2	3	3	3
	xDSL 165	3	3	3	2	2	3	3	3
	xDSL 170	3	3	3	2	2	3	3	3
	xDSL 175	3	3	3	1	1	3	3	3
	xDSL 180	3	3	2	1	1	3	3	3
	xDSL 185	3	3	2	1	1	3	3	3

1 = ends at ~60KHz, 2 = ends at ~86KHz, 3 = ends at ~103KHz

Table 13. NON EC Smart LDSL: Upstream Selection Table

		Downstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
selection index	xDSL 10	1	1	1	1	1	1	2	1
	xDSL 11	1	2	1	1	1	2	1	1
	xDSL 12	1	2	1	1	1	2	1	1
	xDSL 13	1	2	2	1	1	2	1	1
	xDSL 160	1	2	1	1	1	2	2	1
	xDSL 165	1	2	1	1	1	2	2	1
	xDSL 170	1	2	1	1	1	2	2	1
	xDSL 175	1	2	1	1	1	2	2	1
	xDSL 180	1	2	1	1	1	2	2	1
	xDSL 185	1	2	1	1	1	2	1	1

1 = starts at ~ 120KHz ; 2 = starts at ~ 138KHz

Table 14. NON EC Smart LDSL: Downstream Selection Table

[0090] Tables 15 and 16 provide the performance improvement inherent to the NON EC Smart LDSL versus M OJ-074. As can be seen from the tables, this embodiment of a smart system performs better than the system disclosed in M OJ-074. This embodiment of a smart system compensates for the M OJ-074 Upstream channel weaknesses in the presence of SHDSL and HDSL.

upstream difference with M OJ-074							
case 1	case 2	case 3	case 4	case 5	case 6	case 7	
Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
0	0	0	10	9	0	0	7
0	0	0	35	37	0	0	4
0	0	0	35	33	0	0	4
0	0	19	43	41	6	0	3
0	0	0	32	28	0	0	5
0	0	0	37	34	0	0	4
0	0	0	32	34	0	0	4
0	0	0	35	35	0	0	3
0	0	2	42	38	0	0	4
0	0	5	42	40	0	0	3

Table 15. (NON EC SMART LDSL US rate – M OJ074 US rate)

downstream difference with M OJ-074							
case 1	case 2	case 3	case 4	case 5	case 6	case 7	
Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
219	52	162	125	178	63	0	136
63	0	14	41	66	0	0	56
63	0	12	24	56	0	0	57
30	0	0	9	40	0	0	27
108	0	53	45	91	0	0	98
97	0	43	45	86	0	0	88
86	0	34	44	81	0	0	73
75	0	27	42	74	0	0	68
66	0	26	40	68	0	0	58
56	0	21	37	60	0	0	50

Table 16. (NON EC SMART LDSL DS rate – M OJ074 DS rate)

[0091] Figures 4-19 show bar chart performance plots of ADSL2, non-EC smart LDSL and the system disclosed in M OJ-074, for the above described noise cases..

[0092] EC Smart LDSL system

[0093] Definition

[0094] As described above, a first exemplary smart system may make use of U1, U2, U3 and D1, D2, D3. In accordance with the features of all these masks, an Echo canceller may be advantageous when D2 is used. A second exemplary smart system may be identified as the EC Smart LDSL. For this embodiment, the Smart LDSL system may have the capability to analyze *a priori* the cross talk/physical layer

conditions for all the Smart LDSL modems located in the same area. In addition the system may detect the same type of cross talks/impairments and, therefore, the worst case self NEXT due to the Downstream mask D2 may only apply when this mask is used.

[0095] EC Smart LDSL: Simulation results

		upstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
EC SMART LDSL	xDSL 10	839	841	488	310	324	458	456	423
	xDSL 11	667	667	312	179	196	283	280	253
	xDSL 12	622	623	270	146	157	242	239	214
	xDSL 13	496	496	176	102	110	142	135	130
	xDSL 160	709	710	353	206	219	324	321	291
	xDSL 165	675	675	319	182	195	291	288	259
	xDSL 170	641	641	287	152	168	259	256	229
	xDSL 175	606	606	255	136	145	227	225	200
	xDSL 180	572	572	226	122	130	198	195	168
	xDSL 185	537	537	200	108	116	169	166	139

Table 17. EC Smart LDSL Upstream Channel Performance Results

		Downstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
EC SMART LDSL	xDSL 10	2615	1711	1946	2148	2169	1679	381	719
	xDSL 11	1060	407	445	902	958	358	**54**	193
	xDSL 12	1265	643	634	998	1025	546	**38**	**140**
	xDSL 13	885	398	449	705	816	350	**18**	**80**
	xDSL 160	2156	1333	1466	1797	1816	1268	216	476
	xDSL 165	1885	1086	1222	1572	1604	1027	**140**	388
	xDSL 170	1639	875	967	1370	1413	809	**86**	308
	xDSL 175	1418	754	782	1187	1237	648	**62**	237
	xDSL 180	1213	633	720	1025	1079	579	**28**	**181**
	xDSL 185	1034	529	629	877	932	500	**20**	**127**

Table 18. EC Smart LDSL Downstream Channel Performance Results

		Upstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
EC SMART LDSL	xDSL 10	3	3	3	2	2	3	3	3
	xDSL 11	3	3	3	2	2	3	3	3
	xDSL 12	3	3	3	1	2	3	3	3
	xDSL 13	3	3	2	1	1	2	2	1
	xDSL 160	3	3	3	2	2	3	3	3
	xDSL 165	3	3	3	2	2	3	3	3
	xDSL 170	3	3	3	2	2	3	3	3
	xDSL 175	3	3	3	1	1	3	3	3
	xDSL 180	3	3	2	1	1	3	3	2
	xDSL 185	3	3	2	1	1	3	3	2

1 = ends at ~60KHz, 2 = ends at ~86KHz, 3 = ends at ~103KHz

Table 19. EC Smart LDSL: Upstream Selection Table

		Downstream							
		case 1	case 2	case 3	case 4	case 5	case 6	case 7	
		Self Ne	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
EC SMART LDSL	xDSL 10	2	2	2	2	2	2	1	1
	xDSL 11	2	3	2	2	2	3	1	1
	xDSL 12	2	3	2	2	2	3	1	1
	xDSL 13	2	3	3	2	2	3	1	1
	xDSL 160	2	3	2	2	2	3	1	1
	xDSL 165	2	3	2	2	2	3	1	1
	xDSL 170	2	3	2	2	2	3	1	1
	xDSL 175	2	3	2	2	2	3	1	1
	xDSL 180	2	3	2	2	2	3	1	1
	xDSL 185	2	3	2	2	2	3	1	1

1 = starts at ~ 120KHz ; 2 = starts at ~ 138KHz

Table 20. EC Smart LDSL: Downstream Selection Table

upstream difference with M OJ-074							
case 1	case 2	case 3	case 4	case 5	case 6	case 7	
Self Ne)	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
0	0	0	10	9	0	-54	-421
0	0	0	35	37	0	-52	-416
0	0	0	35	33	0	-50	-410
0	0	19	43	41	6	-41	-367
0	0	0	32	28	0	-53	-420
0	0	0	37	34	0	-52	-418
0	0	0	32	34	0	-51	-413
0	0	0	35	35	0	-50	-408
0	0	2	42	38	0	-48	-405
0	0	5	42	40	0	-46	-400

Table 21. (EC SMART LDSL US rate – M OJ074 US rate)

downstream difference with M OJ-074							
case 1	case 2	case 3	case 4	case 5	case 6	case 7	
Self Ne)	ADSL	ISDN	SHDSL	HDSL	MIX	TIA	T1
219	52	162	125	178	63	157	283
63	0	14	41	66	0	54	114
63	0	12	24	56	0	38	92
30	0	0	9	40	0	18	28
108	0	53	45	91	0	66	145
97	0	43	45	86	0	48	127
86	0	34	44	81	0	33	103
75	0	27	42	74	0	37	85
66	0	26	40	68	0	24	70
56	0	21	37	60	0	20	51

Table 22. (EC SMART LDSL DS rate – M OJ074 DS rate)

[0096] Figures 20-35 show bar chart performance plots of ADSL2, EC smart LDSL and the system disclosed in M OJ-074, for the above described noise cases.

[0097] Smart DSL Implementation based on ITU-T Recommendation G.992.3

[0098] Two steps

[0099] Deciding to access one of the mask amongst all the possible choices offered by a smart DSL platform may be facilitated by using a two step process in the following order:

[00100] (1) Masks Choice based on Performance/Physical layer status criterion: Smart functionality; and (2) Protocol to activate one particular mask based on CP/CO capabilities.

[00101] Step (1): Mask Choice based on Performance/Physical layer Status: Smart Functionality.

[00102] Figure 36 displays the organizational chart that describes the two selection modes inherent to smart DSL: manual or automatic.

[00103] The automatic selection may be completed in two different ways: by making use of the Line Probing capabilities of G.992.3 (LP Option) or by trying different masks up to the training and choosing at the end the best (Many Tests Option). Figure 37 gives the state diagram of the two approaches to automatically select a pair of mask for a smart DSL platform.

[00104] The LP option needs to complete the right loop of operations in figure 37 one time only. The Many tests option requires to complete the left loop of operations in figure 37 as many times as the number of available possibilities.

[00105] Step 2: Protocol to activate one mask based on CO / CP capabilities.

[00106] This section discloses three protocol examples to activate one mask based on CO/CP capabilities.

[00107] Option 1: CP decides

[00108] Figure 38 describes the "CP decides" which mask is to be used sequence, based on G.992.3. CLR and CL allow CP and CO to signify their list of capabilities.

[00109] Option 2: CO decides

[00110] Figure 39 describes the "CO decides" which mask is to be used sequence, based on G.992.3, after being requested by the CP to do so. CLR and CL allow CP and CO to signify their list of capabilities.

[00111] Option 3: CP is overruled by CO

[00112] Figure 40 describes the "CO overrules CP" about which mask is to be used sequence, based on G.992.3, after CP has mentioned which mask is to be used . CLR and CL allow CP and CO to signify their list of capabilities.